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CONTENTS OF SERIES II, VOLUME 5

PAGE

Title page i
Contents iii
The Pleistocene Faunas of Asia and Their Relationships to Early Man. By Edwin H. Colbert 1
The Action of the Heart and Circulation During Diving. By Laurence Irving 11
The Problem of Fear. By John Dollard 17
New Members 19, 42, 84, 128, 156, 185, 201
The Dating of Diastrophic Events in Southern Nevada. By Chester R. Longwell 21
Some Morphological Adaptations of Cetaceans (Whales and Porpoises) for Life in the Water. By Henry C. Raven 23
Primitive Law and Modern. By E. A. Hoebel 30
Some Recent Studies on Photoperiodicity in Animals. By Thomas Hume Bissonnette 43
Report of the Annual Meeting. By Eunice Thomas Miner 52
New Methods in Stellar Dynamics. By S. Chandrasekhar. (Abstract by Professor Jan Shilt) A. Cressy Morrison Prize Winner, 1942 57
Comparative External Anatomy, Phylogeny, and a Classification of the Bees. By Charles D. Michener. (Abstract) A. Cressy Morrison Prize Winner, 1942 57
The Relation between Centriole and Centromere in Atypical Spermatogenesis of Viviparid Snails. By Arthur W. and Priscilla F. Pollister. (Abstract) Honorable Mention, A. Cressy Morrison Prize Competition, 1942 58
The Haplolepidae, a New Family of Late Carboniferous Bony Fishes. By T. Stanley Westoll. (Abstract) Honorable Mention, A. Cressy Morrison Prize Competition, 1942 60
Genetic Studies of Speciation in the Swordtail-Platyfish Group and of the Experimentally Produced Hybrids. By Myron Gordon 63
Cultural and Thematic Analysis of Fictional Films. By Gregory Bateson .. 72
On the Problems of German Characterology. By Erich Fromm 79
Gravity Anomalies in Sedimentary Basins. By Dorr C. Skeels 87
Time Culture Method in Recent Investigations. By Robert Chambers 92
Negro-White Interpersonal Relationships in a Limited Environment. By Theodora M. Abel 97
Themes in Japanese Culture. By Geoffrey Gorer 106
Conference on "High Polymers" 125
Conference on "Psychosomatic Disturbances in Relation to Personnel Selection" 126
Announcement, A. Cressy Morrison Prize Contest, 1943 127
Ring-dikes and Their Origin. By Marland P. Billings 131
Personality Development and the Social Psychology of Peace. By Eugene Lerner 145
Food, Time, and Culture. By G. Evelyn Hutchinson 152

PAGE
Conference on "Parasitic Diseases and American Participation in the War".... 155
Deep-focus Earthquakes. By WILLIAM A. LYNCH..... 159
Problems in the Behavior and Evolution of a Species of Blind Cave Fish. By CHARLES M. BREDER, JR..... 168
Anthropological Approach to Dietary Problems. By MARGARET MEAD..... 177
Conference on "Sulfonamides"..... 183
Announcement of Publications for 1943..... 184
Mapping by Photogrammetric Methods. By GERALD FITZGERALD..... 187
Reconnaissance Mapping by Photogrammetric Methods. By GERALD FITZGERALD..... 187
Studies on the Chemistry of Chromatin. By A. E. MIRSKY AND A. W. POLLISTER..... 190
Some Aspects of the Problem of Unsuccessful Personality Screening. By DAVID SHAKOW..... 199
Conference on "Magneto Chemistry"..... 200

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SECTIONS OF GEOLOGY AND MINERALOGY

OCTOBER 5, 1942

DOCTOR EDWIN H. COLBERT, The American Museum of Natural History, New York City, N. Y.: *The Pleistocene Faunas of Asia and Their Relationships to Early Man.* (This lecture was illustrated by lantern slides.)

Within the past decade a great deal of attention has been devoted to the Pleistocene mammalian faunas of Asia, partly as a result of the discovery of the so-called Peking Man, *Sinanthropus pekinensis*, at Choukoutien, and, more recently, of the discovery of additional materials of the so-called Java Man, *Pithecanthropus erectus*, on the Island of Java. The separate discoveries of these extraordinarily important remains of ancient man in Asia were bound to stimulate all sorts of studies having to do with subjects related to early man in the Orient. Obviously one of the questions that loomed large in a consideration of the primitive human populations of Asia was that of the contemporaneous mammalian faunas. With what animals did early man in the East associate himself, and what is the significance of these mammalian assemblages with regard to the environment of the time? How may such mammalian faunas be utilized for dating early man in Asia?

Yet aside from the problem of early man, which is so interesting to us, Asia is none the less significant to the paleontologist interested in the later history of vertebrate life on the earth, for Asia occupies a central position among the continents of the world. It is a continental focal point, surrounded at greater and lesser distances by land masses to which it was, in Pleistocene times, readily accessible. This may readily be seen

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by a glance at a world map with the Pleistocene continental outlines restored. Here Asia appears, especially if a North Polar projection is used, near the center of the continental land masses, the eastern part of the great Eurasian continent. To the southwest is Africa, joined to the Eurasiatic continent by broad land connections. To the southeast is the East Indian region, not a series of islands as we know them, but a long peninsula, pointing its finger at Australia. And in the other direction, to the northeast, is the North American land mass, joined to Asia by a broad trans-Bering bridge, and in turn connected to South America via the still persistent Isthmus of Panama. Thus it is evident that Asia held a central position in the Pleistocene world of connected continents, a position from which active animals might push out in almost any direction, a position through which animals going from east to west and from west to east would have to pass. It is this great region, as it existed in Pleistocene times, with which we are concerned in the present contribution.

The study of Asiatic mammals of the Pleistocene may best be approached, however, by a subdivision of the general large Asiatic region into several distinct areas, dependent upon the location of the most prolific fossil-bearing localities, for the problem is too large and diffuse to be grasped by a single, undivided survey. Asia may be divided accordingly into five general areas, namely: the Indian region, in which are found the famous Siwalik faunas, the Narbada fauna and faunas of more recent age; the region of Burma, producing the Irrawaddy faunas and the cave assemblages of Mogok; the region of South China and Indo-China, in which are found terrace or floodplain deposits containing early Pleistocene mammals and later cave deposits extensively developed, such as the one at Yenchingkou in Szechwan Province; the region of the Malay Peninsula and the East Indies, notable because of the succession of faunas in Java; and finally, the region of North China with various faunas, of which the earlier Nihowan assemblage and the later Choukoutien fauna are of particular importance. (Incidentally it should be noted that of these five regions, the first four are included in the present-day Oriental zoogeographic realm, while the last one, namely the North Chinese region, falls within the present-day Palearctic zoogeographic realm.) It is in part by a comparison of the succession of faunas in these five regions that the Pleistocene history of Asia has today assumed the form of a logical and clear-cut story.

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The Villafranchian in Asia

One of the vexing problems that arises in any discussion of the Pleistocene in Asia (or in other parts of the world, for that matter) has to do with the delineation of the boundary between the Pliocene and Pleistocene periods. This is a problem of considerable importance because unless the limits of the Pleistocene period are definitely understood there will be confusion as to the entire larger problem of the Pleistocene faunas under consideration. In a measure there is a similar problem that applies to the boundary that may be drawn between Pleistocene and Recent times, but this problem is of less fundamental importance than the one dealing with the lower limit of the period, and need not be considered at this place. Furthermore, the subject of a Pliocene-Pleistocene boundary inevitably comes around to the much-discussed "Villafranchian problem," and it is only by a resolution of the Villafranchian problem in one direction or the other that a clear understanding may be had of what is intended when the word "Pleistocene" is mentioned.

The Villafranchian is named from the locality of Villa Francha d'Asti in Italy where there is found a very characteristic mammalian fauna. This Villafranchian fauna is notable for the first appearance in it of certain modernized mammals, notably the modern horse of the genus *Equus*, the first mammoths, *Archidiskodon*, and the first true cattle of the general *Bos* group. These are immigrant forms, the horse coming in from America, the mammoth, and probably the cattle also, from India or a closely adjacent region. Indeed, these Villafranchian elements, if so they may be called, appear almost simultaneously as migrants at widely separated regions in North America, Eurasia, the Orient and Africa, at a period just preceding the advance of the first continental glaciers from the north. Thus many paleontologists argue that the sudden "explosion" of certain modernized and widely ranging mammalian types from their centers of origin—the New World in the case of the horse and the camel (which reached many localities in Asia), the Old World in the case of the mammoth and the cattle—constitutes a valid and practicable datum to serve as a marker for the beginning of Pleistocene history. In accordance with this view the development of the Villafranchian faunas, a world-wide phenomenon, is regarded as the opening phase of the Pleistocene period.

ORIGIN AND SPREAD OF CERTAIN DIAGNOSTIC MAMMALS IN VILLAFRANCHIAN TIMES

	Africa	Europe	Asia	North America	South America
Horse	x←———	x←———	x←———	origin———	→x
Camel		x←———	x←———	origin	
Cattle	x←———	x←———	origin———	→x	
Mammoths	x←———	x←———	origin———	→x	

As against this view there is the school of thought that would regard the Villafranchian as marking the last expression of Pliocene history, a school which finds among its leaders the distinguished paleontologist, P. Teilhard de Chardin. Teilhard, as a result of his studies in Asia, has noted that the Villafranchian faunas of China, containing horse and mammoth, are on the whole of a subtropical nature, living, as is shown by the sedimentary evidence, at a time of extensive lake formation. The end of this Villafranchian lake stage in China, especially in North China, was marked by vigorous diastrophism during which the deep gorges of the Yangtze River were cut. After this period of gorge cutting there was a change in the physiographic expression of the land surface in China, accompanied by the advent of man in the primitive form of *Sinanthropus*. Upon the basis of this history Teilhard prefers to regard the Pleistocene in China, and in Asia generally, as beginning with the period of diastrophism and consequent gorge cutting subsequent to the development of the Villafranchian stage.

SUCCESSION OF PHYSIOGRAPHIC AND FAUNAL STAGES IN NORTH CHINA

Loess	Modernized man
Loam	First appearance of man
Gorge Cutting	
Lake Deposits	Horse ←——— From
	Camel←——— N. America
From———→	Cattle
India———→	Mammoth
	+
	Subtropical Fauna

So it is that there are two sets of criteria for marking the beginning of the Pleistocene in Asia, and they may be represented in the following manner.

	Faunal Evidence	Physiographic Evidence
Pleistocene		
		Break
Villafranchian		Gorge Cutting
	Break	
Pliocene	Influx of advanced fauna	

It is hereby proposed that the Villafranchian should be included within the Pleistocene period, since it is felt that the world-wide intercontinental migrations of certain modernized types of mammals such as the horse, camel, cattle and mammoth constitute a better datum for marking the beginning of Quaternary times than does the diastrophic movements which came at the end of the Villafranchian in Asia.

The Lower Pleistocene Faunas of Asia

These are the faunas showing a characteristic Villafranchian stage of development, marked by the appearance of new and modernized types of mammals, some autochthonous, others immigrant forms. Among these Lower Pleistocene assemblages are the famous and rich Upper Siwaliks fauna of India, the Upper Irrawaddy fauna of Burma, the Djetis fauna of Java, the rather scanty Ma-Kai fauna of southern China and the Nihowan fauna of North China. That these faunas are closely related is shown by the identity or the close resemblances between certain important elements comprising each assemblage. Thus they may be compared in a general way as follows.

	India	Burma	E. Indies	S. China	N. China
Stegodont	x	x	x	x	
Mammoth	x	x	x		x
Rhinoceros	x	x	x	x	x
Horse	x	x		x	x
Hippopotamus	x	x	x		
Camel	x				x
Cattle	x		x		
Orang	x		x		

Certain of the differences between these faunas possibly are caused by the accidents of collecting; thus the fauna of South China is so scanty

that it certainly does not represent a true picture of the mammalian life of that time in that region. On the other hand, some of the differences between the faunas probably reflect a real difference that existed at the time the animals were living. For instance, the lack of *Hippopotamus* in China very likely may be owing to the fact that these aquatic animals, seemingly of Indian origin, never reached the more eastern and northern portions of Asia. Likewise, the lack of camels in the East Indies may be attributed to the fact that these animals, coming into Asia from the northeast, never pushed into the then peninsular part of the Indies.

The noteworthy fact about this fauna is the absence of human elements in it. The higher primates appear in some regions in the form of orangs, but no human fossils are to be seen—an absence that may be accidental, but which on the other hand may be very real, reflecting the true conditions of the faunal composition at that time.

Conjectures as to the origin and direction of spread of the mammals comprising these Lower Pleistocene faunas of Asia are at best rather tenuous, but there is good reason to believe that the bulk of the mammals pushed out from an Indian center of origin—excluding of course certain immigrant forms such as the horse and the camel.

The Middle Pleistocene Faunas of Asia

These are the earliest post-Villafranchian faunas of Asia, which are set apart from the Lower Pleistocene mammalian assemblages by the very profound diastrophic break that so completely separates Villafranchian and post-Villafranchian history in this part of the world. Through China and into Burma these faunas are found in limestone caverns and fissures. In fact, the conditions of deposition and preservation of this "cave complex" are so similar in the various regions where they are found that, even without the evidence gained from the composition of the faunas, there can be but little doubt that we are looking at essentially a widely spread single assemblage of mammals. As cave fossils, there is a Middle Pleistocene fauna found at Mogok in Burma, Hoshangtung in Yunnan, and at various localities in southern China, notably Yenchingkou in Szechwan, the Kwangsi caves, and Tanyang cave near the mouth of the Yangtze. This southern cave fauna is related to the northern cave fauna of Choukoutien, and relationships may be traced between it and the stream-deposited faunas of the Narbada valley in India and the famous Trinil locality in Java.

	India	Burma	E. Indies	S. China	N. China
Porcupine		x	x	x	
Bamboo rat		x	x	x	
Giant Panda		x		x	
Stegodont	x	x	x	x	
Mammoth	x	x	x	x	
Rhinoceros	x	x	x	x	x
Horse	x				x
Hippopotamus	x		x		
Camel					x
Cattle	x		x	x	
Orang			x	x	
Man (*Pithecanthropus*)			x		x

These Middle Pleistocene faunas, especially as they are developed in the caves of China and Burma, are characterized by the prominence of porcupine, panda, stegodonts, mammoths and rhinoceros as constituent elements. The faunas outside of the cave areas, particularly as developed in India and North China, show differences from the South Chinese and Burma assemblages that probably are not to be explained entirely by the accidents of collecting.

Naturally, *Hippopotamus* would not be expected in cave deposits developed in upland regions. Yet it is to be noted that the cave faunas, as well as the southeastern fauna of Java, are marked by the absence of horses and camels, although other ungulates occur in them, notably rhinoceros and certain types of cattle. These are the local variations that are bound to occur when faunas are being compared over a wide area.

As in the Lower Pleistocene faunas, *Orang* is present in the East Indies, and at this stage it is especially prominent in the South China assemblages. The fact of prime importance in this connection, however, is the appearance of primitive man in two areas, namely Java and North China. This marks the first appearance of man in Asia, and he is in a notably primitive stage of development, namely the stage which has been designated as *Pithecanthropus* in the south and as *Sinanthropus* in the north. (Incidentally, in spite of the generic differentiation that has been accorded to the human remains of North China and of Java, they represent essentially a single type of man.)

Therefore the evidence of the mammalian faunas supports the view, first proposed some years ago by Dietrich and by other authors, that primitive man, as we know him, did not appear in Asia until Middle Pleistocene times, and supplants the earlier idea which accorded a Lower Pleistocene age to *Pithecanthropus*.

The directions of movement of the Middle Pleistocene faunas in Asia are perhaps even less clear than is the case for the Lower Pleistocene faunas. In fact, the evidence would seem to indicate simultaneous migrational flows in several directions: of Indian (Narbada) forms eastward into China, of Chinese forms westward into Burma, of northern forms southward into Java, and of Javanese forms northward into the continental area. The validity of such a picture can only be conjectured; at best it cannot be taken too literally.

The Upper Pleistocene Faunas of Asia

Although a break between the Middle and Upper Pleistocene is to be discerned in Asia, it does not have the dimensions nor the significance of the post-Villafranchian interval of diastrophism. Consequently the Upper Pleistocene history of the region is more or less a continuation of its Middle Pleistocene history, a fact that is reflected to a large extent by the faunas. The Middle Pleistocene faunas continue into Upper Pleistocene times, with perhaps the disappearance of some older forms and the appearance of a few newer types to mark the change. Upper Pleistocene deposits are developed: such as the Potwar loess of India, the later terraces of the Irrawaddy River valley, the Ngandong deposits of Java, the Heichlungstun shelter deposits of southern China and the upper cave deposits at Choukoutien.

	India	Burma	E. Indies	S. China	N. China
Red dog or dhole			x		x
Stegodont			x		
Mammoth		x	x		
Rhinoceros	x		x		x
Horse	x				x
Hippopotamus			x		
Camel					x
Cattle	x	x	x		x
Man (*Homo*)	x	x	x	x	x

The noteworthy fact shown by this list is the relative paucity of fossils in many of the Asiatic localities, a circumstance to be explained probably by the accidents of collecting rather than to any real diminution of the faunas in Upper Pleistocene times. As already remarked, the Upper Pleistocene was really a continuation to a large extent of the Middle Pleistocene in Asia, and in view of the many resemblances of

Middle Pleistocene mammals to Recent mammals of the Asiatic region there is reason to think that these animals continued with but minor extinctions into Upper Pleistocene times. The explanation is probably to be found in the fact that, in many localities such as those of India and North China, the deposits are aeolian loess, not conducive to the preservation of fossil faunas. In others, such as Burma, the deposits are such that fossils are very scanty, and when found are badly damaged by the action of water.

It will be noted that where the Upper Pleistocene faunas are well preserved, notably in the East Indies, they are composed in the main of a continuation of the Middle Pleistocene elements. The one very important and noteworthy addition to the Upper Pleistocene faunas of Asia is that of modern man, *Homo*. Man, in a paleolithic stage of development that is essentially neanderthaloid, as shown by the fine series of skulls discovered by von Koenigswald in the Ngandong deposits of Java, and by the flint industries discovered in the Soan valley of India and in the upper cave deposits and the loess of China, appeared in Asia to supplant his pithecanthropoid ancestor. Thus the stage was set for the later history of Asia, involving the changes in faunas and the shifting of human populations that led into Recent times.

The Transition into Recent Times

It is difficult to draw a hard and fast line between the Pleistocene and the Recent, owing to the fact that, being so close to this transition, we can see those details which have been preserved to mark it as a gradual change. Various criteria have been adopted to mark the boundary between the Pleistocene and our modern age, just as various criteria have been used to designate the Pliocene-Pleistocene boundary. Perhaps for our purposes, the change from what we might call the Pleistocene faunas into Recent faunas can be used to mark this change.

Our Recent mammalian faunas are essentially impoverished Pleistocene faunas—impoverished by the rather sudden and inexplicable extinction of various large typical Pleistocene mammals over vast continental areas. Thus in Asia, the transition from the Pleistocene into the Recent, a transition that seemingly occurred only a few thousand years ago, was the period during which many large proboscideans, the stegodonts and the "mammoths" disappeared from the face of the land; when there was an extinction in the Asiatic region of the Pleistocene type of hyena (related to the modern African hyenas) and of the hippopotamus. Other

mammals, still living in limited areas of Asia, would seem to have had their widespread ranges contracted during this transitional period, so that they were in effect extinguished over a greater portion of the Asiatic region. Such were the giant pandas, the tapirs and the rhinoceroses.

Finally, this transition was the time during which modern Asiatic man in a Neolithic stage of development pushed out in migrations and counter-migrations to set the pattern for the Recent distribution of man in the Orient. These movements were extremely complex and involved, and need not be discussed here. Suffice it to say that this was the time at which the mongoloids migrated to the east, through the Bering region, to cross from the Old World into the Western Hemisphere and thus populate a New World.

Summary

The Pleistocene faunal history of Asia is divisible into two phases, sharply separated, each from the other, by a pronounced diastrophic break. The first or earlier phase is comparable to the Villafranchian of Eurasia and to the basal or Lower Pleistocene of North America, and is marked by the appearance of numerous advanced mammalian genera, some immigrants, other autochthonous. In this stage of the Pleistocene of Asia there is as yet no indication of the presence of primitive man.

The second or later phase of the Pleistocene faunal history of Asia is the post-Villafranchian stage, comprising Middle and Upper Pleistocene times. The Middle Pleistocene, coming immediately after the post-Villafranchian diastrophism in Asia, is characterized throughout China and Burma by the development of cave faunas showing close relationships to each other. It was at this time that man first appeared in Asia (at Trinil in Java and at Choukoutien in North China) in a pithecanthropoid stage of evolution. The Middle Pleistocene history of Asia passes without any very sharp breaks into Upper Pleistocene, with a continuation of the characteristic faunas, now developed in loess and terrace deposits. The most noteworthy change to be seen between these two ages is the disappearance of *Pithecanthropus* and the appearance of Neanderthal man, as shown by skulls found in the Ngandong horizon of Java, and by stone industries from India and China.

The transition from Pleistocene to Recent times in Asia is marked by the extinction of certain large animals from the Pleistocene faunas, and by the appearance of Neolithic man, who spread from his Asiatic homeland via a trans-Bering route into the New World.

SECTION OF BIOLOGY

OCTOBER 12, 1942

PROFESSOR LAURENCE IRVING, Edward Martin Biological Laboratory, Swarthmore College, Swarthmore, Pa.: *The Action of the Heart and Circulation During Diving.* (Illustrated by lantern slides.)

Diving seems, at first consideration, to be an unusual activity for a mammal because of the stress that diving places on a respiratory mechanism using air. But several orders, like the whales, seals and manatees, are thoroughly aquatic, and depend entirely upon diving to secure their food. A number of species from other orders, like the otters and beavers, live largely by means of their facility for feeding or working under water. These animals do not merely exist in a precarious state, but they flourish in large numbers, and form a considerable part of the total mammalian population, as can be seen by examining the records of the whale fisheries and fur trades.

From these recorded numbers, it appears that the divers successfully overcome any handicap imposed by diving habits which must place considerable stress upon a mammalian type of respiration dependent upon a good supply of fresh air. As a matter of fact, divers can easily suspend breathing for from 10 minutes to 1 hour. This ability to suspend breathing places the divers in sharp contrast with the non-divers that find difficulty in a minute or two of arrested breathing. The diving mammals are not of one related group, but they sometimes appear as single species, like the hippopotamus, among orders that are usually entirely terrestrial.

The common occurrence of diving species suggests the use for diving of faculties that are widespread among mammals. The use that the divers have made of their ability and the handicap, and even danger, imposed by the briefness of our ability to tolerate arrested breathing stimulate our interest in the respiratory reactions that are involved in diving. Their widespread occurrence indicates that we should look at a number of species, in order to compare their respiratory adjustments for diving and to see if they do not indicate the accentuation in the divers of common faculties of mammalian respiration.

The action of the heart and circulation can be especially well seen in the arrested breathing of divers. The earlier studies have already been reviewed (Irving, 1939), and references to them will be found in that review. Like many other early and significant observations on respira-

tion, the slowing of the heart, or bradycardia, was first remarked upon by Paul Bert. In several other diving birds, the cormorant, goose and swan, bradycardia was observed by Noel Paton. It was first reported in mammals in the muskrat, by Koppanyi. I observed that when a beaver's head was pushed under water the heart could be felt to slow, and that, during the natural pauses in breathing of seals (*Phoca vitulina*), the heart usually slowed to half of its frequency while breathing.

Scholander (1940) showed by electrocardiograms that during experimental dives the hearts of seals (*Halichoerus* and *Cystophora*) slowed to one-fifth or even one-tenth of the rate while breathing. The change in heart rate was so rapid that the next beat after submersion might be delayed for 10 seconds.

In a series of studies marking a very pleasant collaboration, Dr. Scholander and I have continued together the investigations that we had begun separately. In the seals, *Phoca vitulina*, the bradycardia is as prompt and well sustained as in *Halichoerus* and *Cystophora* (Irving, Scholander and Grinnell, 1942a). Electrocardiograms of the hearts of porpoises (*Tursiops truncatus*) swimming in the open sea showed that they reacted to each dive by a bradycardia, but that in their short dives it was not as conspicuous as in the seal (Irving, Scholander and Grinnell, 1941a). By skillful management, Miss Henrietta Safford accomplished the difficult task of securing electrocardiograms from diving minks (*Mustela vison*), and found that the bradycardia was conspicuous even in their short dives. It would be interesting to examine the heart action of the mustelids and to compare the aquatic otter with the aquatic-terrestrial mink and terrestrial-arboreal martin.

The bradycardia of diving is not restricted to born divers, for it appears in the sloths, *Choloepus* and *Bradypus*, when their breathing is arrested (Irving, Scholander and Grinnell, 1942b). The armadillo, *Dasypus novemcinctus* (Scholander, Irving and Grinnell, unpublished), likewise shows the bradycardia. In fact, bradycardia would probably be observed in any mammal if the means of observation were properly arranged, for we have always observed it when the technique gave satisfactory records.

In skilled human divers, bradycardia occurs during diving, and we have recorded heart frequencies as slow as 30 per second in a man during vigorous swimming under water (Irving, Scholander and Grinnell, 1941a). The bradycardia can be observed most readily in men and women accustomed to swimming, but we are not convinced that the extent of

bradycardia is proportional to the ability of the human diver, because a trained athlete is, for technical reasons, such a superior subject for observation. It is interesting that the easiest animal to study, man, was about the last in which it occurred to us to look for the bradycardia of diving.

The regular occurrence of bradycardia and the fact that it persisted during active swimming suggests that other vascular changes also take place during diving. During spontaneous pauses in the breathing of seals (Irving, Solandt, Solandt and Fisher, 1935) and beavers (Irving, 1937), as the heart slowed, the blood pressure either remained constant, or, sometimes, rose. The maintenance of blood pressure with decreased cardiac activity indicated that constriction of the peripheral circulation compensated for the diminished cardiac activity.

By following the changes in blood flow through tissues with a thermoelectric recorder for blood flow, it was shown that the flow through the muscles of a beaver decreased when the breathing was arrested (Irving, 1937). At the same time, the flow of blood through the brain increased, and this example of selective control of the peripheral circulation gave evidence that, during the diving bradycardia, the circulation was restricted in some tissues, but well sustained in the brain. Looking at the results of such vascular changes, it appeared likely that, during a dive, the decreased muscular blood flow would diminish the speed of exhaustion of the oxygen reserves, while the maintained cerebral flow would provide for the brain the first call upon the oxygen stores.

A series of subsequent studies showed that the selective regulation of the peripheral circulation during arrested breathing commonly occurred in dogs, cats and rabbits (Irving, 1938). The selective control of the circulation was not specific to beaver, nor characteristic of divers alone. The restriction of flow involved the liver as well as the muscles, and thus served to check a large part of the peripheral blood flow. The restriction of muscular flow was controlled by the sympathetic nerves, and, judging from its quickness and apparently purposive nature, it was very nicely regulated.

For technical reasons, it was more difficult to determine the condition of the peripheral circulation of the diving seal, and yet those animals seemed most likely to demonstrate the operation of an electively controlled circulation. During experimental dives of seals lasting 15 or 20 minutes, there was no increase of lactate in the arterial blood, but, immediately after the dive, lactate flooded the circulation (Scholander,

1940). During a long dive, large amounts of lactate were shown to accumulate in the muscles, so that the metabolic processes of the muscles were practically isolated from the circulation (Scholander, Irving and Grinnell, 1942). The steady formation of lactic acid in the muscles of rats during short dives had also been shown (Scholander, 1940). The deferred escape of lactic acid also appeared in the dives of the Florida manatee (*Trichechus latirostris*), (Scholander and Irving, 1941).

The isolation of the muscles from the circulation could be accomplished by constriction of the peripheral circulation. That constriction occurred was indicated by observations that Scholander (1940) made upon the lack of bleeding from vessels cut during dives. It was also suggested by the common retardation of the muscular circulation during arrested breathing, by the bradycardia, and by the sustained blood pressure during the bradycardia during spontaneous pauses in breathing (Irving, 1939). In the seal, during dives, the arterial blood pressure remained about normal, in spite of recorded heart frequencies one-tenth of those during breathing (Irving, Scholander and Grinnell, 1942a). Simultaneous records of changes in muscular blood flow and heart frequency in seals, as recorded by the thermoelectric blood-flow meter and electrocardiograph, showed that the flow through the muscles diminished immediately as the heart slowed down, and was promptly restored in recovery (Grinnell, Irving and Scholander, 1942). Even the transient fluctuations in heart rate were usually reflected by changes in muscular flow, and the flow record conformed with the view that compensatory peripheral circulatory changes accompanied changes in cardiac action.

It has been suggested that these changes in the circulation might be naturally integrated in a useful set of circulatory adjustments for the conservation of the oxygen stores during diving. A rather clear indication of this situation was provided by simultaneous records of heart changes and oxygen content of arterial blood of seals during diving. Two seals showed the bradycardia developing somewhat more slowly than usual. In those experiments, the observed rate of oxygen use from the blood was more rapid than in two other seals in which the heart slowed promptly (Irving, Scholander and Grinnell, 1941b). It was already known that the end of a seal's safe diving time coincided with reduction of the oxygen content of his blood to about 3 per cent by volume. In the two seals which promptly showed bradycardia, the rate of reduction of the blood extended the use of the oxygen stores over at least 15 minutes. With the slow development of bradycardia, the more

rapid utilization of the oxygen stores led to dangerously low oxygen levels in less than 10 minutes.

It is not a new conclusion that changes in the heart indicate the sum of the changes in the peripheral circulation. But bradycardia is not commonly regarded as a usual mammalian reaction, because, for terrestrial mammals, the air supply for breathing is usually unlimited. For the divers, on the other hand, economy of breathing is essential, and it seems quite certain that the elective control of the circulation allows them to husband their stores of oxygen for selected distribution during a long dive. The sparing of oxygen use so accomplished can only defer the necessity for providing oxygen until recovery makes restitution, so that the net result of this adjustment is only a deferment of the breathing requirements, and not a net saving.

True economy in the use of oxygen appears, to some extent, in the depressed metabolism of the quiet seal during diving (Scholander, 1940) and in the even more conspicuous depression of the sloth's metabolism during arrested breathing (Irving, Scholander and Grinnell, 1942b). The three-toed sloth, *Bradypus*, can easily endure 20 minutes of arrested breathing. During this period the sloth's heart slows down, but the slowing is delayed and small compared with the bradycardia seen in seals. The rate of oxygen use from the sloth's blood is also quite rapid, so that within 8 minutes its oxygen reserves are depleted to a level that would be dangerous for a seal. The sloth, nevertheless, endures well for a further 10 minutes, with practically depleted oxygen stores. Sloths can really endure asphyxia, but seals are not at all resistant to asphyxia and owe their long dives to the nicely controlled use of their available resources.

Other mammals show, more or less well, both hardiness toward asphyxia and vascular adjustments toward arrested respiration. Man appears to have little endurance for asphyxia, and, as indicated by the slight human bradycardia in diving, can make only poor adjustments for sparing his oxygen stores. Men are poor divers in comparison with seals, but even their moderate ability is important when it is all that they have for emergency use when accident or sickness arrests breathing.

The circulatory adjustments of mammals to diving appear to have common characteristics, but the development of these characteristics varies widely in the different species. The variations on the common adjustments seem to give to each species the physiological distinction by means of which respiration provides for the activity of each special habit of life.

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JOINT MEETING

SECTIONS OF PSYCHOLOGY AND ANTHROPOLOGY

October 26, 1942

Doctor John Dollard, Institute of Human Relations, Yale University, New Haven, Conn.: *The Problem of Fear.* (This paper was prepared under the joint authorship of Doctors John Dollard and Neal E. Miller.)

The association of fear responses to danger cues seems to take place by the usual mechanisms of learning. Fear responses made in circumstances of battle are no exception to this rule. Those who know the dangers peculiar to battle conditions are afraid when they go into action. Fear is a drive that, like any other drive, can incite responses that prove adaptive. Fear can make the soldier cunning and properly cautious.

Attention should be concentrated on the fear cues until fear has done its maximum work. When nothing is to be gained by further response to fear stimuli, it seems to be adaptive to take the attention off the signals of fear. Any number of distraction techniques can be used, such as "having something else to do while waiting for attack," singing, playing cards, joking, and the like. When fear must be borne, as it must under battle circumstances, the important thing is to strengthen all drives that compete with fear. Patriotic feelings, loyalties to unit, devotion to comrades, worship of the commander are all secondary drives that can compete successfully against fear.

Opinions seem to vary as to whether men are more or less afraid with repeated exposures to danger. Some seem to be, other not. Fear, of course, is contagious. So, also, is courage. In actual battle situations it seems highly important for the soldier to suppress sounds or gestures indicating pain or fear. It is possible, though by no means certain, that the discussion of fear outside of battle situations is useful. Some say that it reduces the sense of isolation of the soldier. Others add that it increases the force of a good example to know that another man is afraid. Some men seem to fight better when they are afraid, if the perception of their personal danger is accompanied by a parallel perception of danger to the group or society to which they belong. It seems quite likely that unconscious fear is usually dangerous, because unlabeled fear cannot be opposed by thoughts that would tend to control it.

Because of the confidential nature of the research data on which this report is based, it is necessarily sketchy. Also, collection of data has just begun, so that the ultimate form of such a report cannot be formulated at this time.

NEW MEMBERS

Added to the Rolls During the Summer Recess from May 19 to October 22, 1942

LIFE MEMBER

Arnold, Weld, A.B., Astronomy, Aerial Photography, Major, Headquarters, Army Air Forces, Reno, Nev.

ACTIVE MEMBERS

Bateman, John Burraston, Ph.D., Biophysics, Physical Chemistry, Wartime Research for University of Toronto and National Research Council of Canada, Toronto, Canada.

Bender, James F., Ph.D., Speech Pathology, Psychology, Chairman, Department of Speech, Queens College, Flushing, L. I., N. Y.

Buell, C. Eugene, Ph.D., Meteorology, Chief Meteorologist, American Airlines, Inc., New York, N. Y.

Catalani, Arthur P., M.S., Chemotherapy of Clostridia infections, Fellow, Biology, St. John's University, Brooklyn, N. Y.

Choucroun, Nine, D.Sc., Physical Chemistry, Research, Laboratory of Public Health, Cornell University Medical College, New York, N. Y.

Clasby, Edward, J., Meteorology, Assistant Meteorologist, U. S. Weather Bureau, New York, N. Y.

DiCyan, Erwin, Ph.D., Pharmacology, Biochemistry, Director, DiCyan & Brown, Brooklyn, N. Y.

Dingwall, Andrew, Ph.D., Chemistry, Physics, Consultant, New York, N. Y.

Dunning, John Ray, Ph.D., Physics, Associate Professor, Physics, Columbia University, New York, N. Y.

Fein, Abner, B. A., Biology, Biological Analyst for Board of Economic Warfare, New York, N. Y.

Field, William Osgood, Jr., B.S., Geography, Staff Member, American Geographical Society, New York, N. Y.

Frankel, Eduard, Ch.E., Ph.D., Physics, Chemistry, Research Chemist, B. G. Corporation, New York, N. Y.

Girden, Edward, Ph.D., Psychology, Assistant Professor, Department of Psychology, Brooklyn College, Brooklyn, N. Y.

Harris, Thomas H., B.S., Protein Chemistry, Enzymes, Associate Chemist, Enzyme Research Laboratory, U. S. Department of Agriculture, Washington, D. C.

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Hoffman, Josef, Bacteriology, Immunology, Chemistry, Director of Laboratory, Hope Dell, Preakness, N. J.

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Levine, Joseph, M.S., Meteorology, Assistant Meteorologist, Fort Monmouth, N. J.

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Mayo, Frank R., Ph.D., Organic Chemistry, Research Chemist, U. S. Rubber Co., Passaic, N. J.

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Micko, Doretta Vera, Ethnology, Lecturer, Flushing, L. I., N. Y.

Neuberger, Hans H., Sc.D., Meteorology, Assistant Professor, Geophysics, Pennsylvania State College, State College, Pa.
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Stiles, Merritt Henry, M.D., Clinical Research in Low Grade Chronic Illness, Philadelphia, Pa.
Stout, Thompson M., M.S., Vertebrate Paleontology, Stratigraphy, Instructor, Department of Geology, University of Nebraska, Lincoln, Nebr.
Wallerstein, James S., M.A., Bacteriology, Biochemistry, Vice-President, Wallerstein Co., Inc.; President, Overly Bio-Chemical Research Foundation, Inc., New York, N. Y.
Zahn, Otto E. E., M.A., Physics, Chemistry, Geology, Mineralogy, Industrial Engineer, Mishawaka, Ind.

ASSOCIATE MEMBERS

Avery, Bennett Franklin, M.D., Anatomy and Cellular Physiology, Waterhouse Professor of Anatomy; Dean, Boston University School of Medicine, Boston, Mass.
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Marshall, Wallace, M.D., Investigative Dermatology, Psychopathology, Physician and Surgeon, Appleton, Wis.
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Wall, Margaret J., B.S., Viruses, University of Rochester Medical School, Rochester, N. Y.
Westoll, T. Stanley, Ph.D., D.Sc., Vertebrate Paleontology, Morphology, Professor of Paleontology, University of Aberdeen, Aberdeen, Scotland.